(12) # EUROPEAN PATENT APPLICATION

(71) Applicant: INTELLIGENT MEDICINE, INC.
253 Adams Street
Denver, Colorado 80206(US)

(72) Inventor: Howson, David C.
253 Adams Street
Denver Colorado 80206(US)

(74) Representative: Baillie, Iain Cameron et al,
c/o Ladas & Parry Isartorplatz 5
D-8000 München 2(DE)

(54) Device and method for effecting application of a therapeutic agent.

(57) A removable programmable element is used to control operation of a delivery unit, which unit delivers a therapeutic agent to a patient. The programmable element is programmed, while removed from the delivery unit, by a computer that is operationally independent of the delivery unit. The delivery unit requires no microprocessor and can include a plurality of channels for effecting independent delivery of therapeutic agents in each channel under the control of the programmable element. The programmable element is programmed with respect to available protocol information, including patient history, needs and tolerances, as well as therapeutic agent parameters, to thereby establish a flow profile that is customized for a particular patient during each moment of each day. Patient demand for therapeutic agents can also be accommodated with safeguards being included to assure proper dispensing of the demanded agents.

EP 0 188 288 A2

DEVICE AND METHOD FOR EFFECTING

APPLICATION OF A THERAPEUTIC AGENT

Field of the Invention

This invention relates to a device and method for effecting application of a therapeutic agent to a patient.

Background of the Invention

5   Various devices and methods have been heretofore suggested and/or utilized to control delivery of therapeutic agents, such as drugs or electrical energy, to a patient. In addition, various drive mechanisms have heretofore been suggested and/or utilized to effect metering of therapeutic 10   agents to a patient, and various on-board dedicated controllers have also been heretofore suggested and/or utilized.

While improvements in dedicated, self-contained controllers have heretofore been made and/or suggested, 15   meaningful further improvements have presented a problem, primarily due to space limitations which have become more acute as the desire and/or need for smaller sized devices has increased while, at the same time, the desirability and/or need for elements providing increasingly soph- 20   isticated complexity, which often require additional space, has also increased to the extent that such elements cannot be fitted into this decreasingly available space.

-2-

This has resulted in compromises that often have proved
to be undesirable, at least in some respects. For example,
delivery units capable of delivering therapeutic agents in
liquid form and small enough to be worn on the body of a

5   patient must normally now be single-channeled devices, and
such devices have normally been limited to delivery of a
therapeutic agent at either a controlled rate or a cycled
bolus, with the rate being manually adjustable or auto-
matically changed to programmed levels only up to a few

10 times in any twenty-four hour period (with provision being
also sometimes made for a brief supplemental bolus of
varying size upon demand by the patient or amplitude release
on demand of the patient when combined with a profile of a
programmed waveform).

15   Known systems and methods for programming and con-
trolling delivery units have varied, but generally include a
manual knob or pushbutton, or buttons on a keyboard, which
adjust parameters, and the values of which may be displayed
on a panel.

20   Ambulatory delivery devices capable of delivering
therapeutic agents in liquid form have also been heretofore
suggested and/or utilized. Within this category are del-
ivery units that are implanted into the body of a patient.
Such devices have been typically passive type devices (such

as pressurized medication delivery devices) or have been
adapted from cardiac pacemaker technology, and flow profile
programs for these units have normally been communicated
telemetrically to the unit by a programmer. Several such

5 existing devices use the approach of a keyboard remote to
the delivery unit, while others use a large, desktop
special-purpose computer connected with a telemetry antenna,
with such telemetry using pulse-modulated electromagnetic
fields.

10 The programs contained within such dedicated computers
are designed with a limited number of pre-programmed wave-
forms. Because of the use of a limited selection of pre-
determined profiles, these computers are, in effect, an
extension of manual keyboards, and do not give the user

15 either the capability of specifying the profile waveform
itself, or of combining freely-defined waveform components.
Moreover, these programmers are usually further limited to
programming single-chamber devices.

The telemetered programming systems described above use
20 "random access memory" (RAM) units to store the transmitted
data in the delivery unit. RAM units, however, have inher-
ent disadvantages, which include the need for sustained
power to avoid loss of memory contents, and are designed for
ease and speed of writing into memory as well as reading the

memory contents which results in relatively high suscepti-
bility to transient electromagnetic noise.

Such programmable devices most often require the use of
microprocessors (which depend upon a separate machine pro-
5   gram to operate) as well as a program of user-defined
parameters. Changing flow profiles in most of these devices
entails rewriting the machine program as well as the user
program. The machine program is, however, not accessible to
reprogramming by the user, and the program must therefore be
10 physically replaced since it is normally contained in a
"read only memory" (ROM) unit that is incapable of being
reprogrammed (or is reprogrammable only after physical
removal and special procedures).

In addition, the relative complexity of the machine
15 programs needed for such general-purpose microprocessors
does not easily allow unambiguous proof of all possible
logical states of the processor. While such proof is pos-
sible in theory, it is extremely difficult to demonstrate in
reality, and very expensive to implement. Such proof is
20 therefore limited to relatively simple logic networks and
programs, that are far below the complexity of the typi-
cally-used microprocessor and machine program.

More recently, dual microprocessors have been used to
compensate for the failure potential inherent in single-

processor designs, in order to assure only safe failure
modes. This does not, however, resolve the problem of
ambiguity, and creates a trap for logic states not expli-
citly contained in a truth table used for comparison.

5   Since known devices use specially designed programming
computers, they tend to be very limited in their capability
and the difficulty of writing programs for such computers is
very high. In addition, known devices provide only the
minimum functions needed to program the delivery unit, and
10   do not provide assistive programs or databases.

The status of known devices intended for table or pole
mounting, and used with relatively high flow rates, is some-
what different than for ambulatory devices. Such known
large-volume delivery units, however, normally provide only
15   constant flow rate profiles or combinations thereof. Also,
the controls for such devices are normally local on-board,
and are typically of the keyboard variety which are used in
conjunction with various data displays. Also typically,
currently used devices have microprocessor controls, with
20   the most advanced systems using dual processors for error
detection.

In such devices, a plurality of flow channels have been
provided. Typically, however, a primary channel is used to
supply a fluid which is usually delivered in large volumes,

and a secondary channel is used to supply a smaller volume

of a drug containing fluid (see, for example, U.S. Patent

No. 4,391,598 to Thompson). In this system, the fluid flow

in the primary channel is interrupted only when a manual

5   order is given which also causes commencement of flow

through the secondary channel, and after flow through the

secondary channel has occurred at a known flow rate for a

time period calculated to be coincident with the emptying of

the reservoir associated with the secondary channel, flow is

10 reverted back to the primary channel. In addition, the flow

rate in each channel is constant and set by the user with

on-board controls.

Another form of multi-channel device has also been

suggested in which the flow rate in each channel is a fixed

15 ratio to that of the other channels, depending upon selec-

tion of mechanical elements (see, for example, U.S. Patent

No. 3,737,251 to Berman et al).

Another large delivery unit has been suggested which

can control up to four flow channels, but utilizes a

20 constant flow rate for each channel that is set using on-

board controls.

A single-channel delivery unit has been suggested which

has connectors provided for computer access. However, the

delivery unit and computer are not designed together as a

system. Instead, a user must first provide a computer, and then program the computer for the intended purpose, with communication between the delivery unit and computer being effected by direct wire connection.

5   Summary of the Invention

This invention provides a system and method for application of one or more therapeutic agents to a patient which overcomes many of the disadvantages of known devices and methods such as set forth hereinabove.

10   A computer, such as a general purpose computer, is used to program a programmable element remotely from the delivery unit (which can be a pump), and the programmable element, after placement in the delivery unit, controls operation of the delivery unit, which delivery unit may contain a

15 plurality of channels all of which are controlled by the programmable element to effect delivery of a plurality of therapeutic agents.

Through use of this arrangement, the device and method of this invention allows programming of a therapeutic agent

20 delivery unit (single or multi-channel) to deliver virtually any needed or desired flow rate profile, be it physical matter (such as a liquid) or a form of energy (such as electrical), normally as a function of time, with such profiles being definable by the user or selected from a

database of profiles that does not require machine modi-
fication of the delivery unit. Patient or event triggering
capability is also provided to allow introduction of sup-
plemental profiles, which are later automatically terminated
5 and flow returned to control by the programmed profile, and
each channel is independently or contingently controllable
under fully automatic and unattended operation.

In addition, manual control functions or special
profiles assigned by programming may also be provided, and
10 secure, verifiable means of transmission of data from the
data entry means to the delivery unit may also be utilized,
which transmission means requires neither electrical power
to sustain its contents nor continued connection between
data entry means and delivery means.

15 Since the data entry means is based on a general-
purpose computer, the difficulty of writing applications
software is minimized, and assistive programs are also
provided in the data entry means to aid the user in
specifying the desired flow profile (including, if desired,
20 graphics-based entry means), and provision can also be made
to simulate the action of the delivery unit, both physically
and pharmacokinetically. Extensive error-reduction means,
including use of databases for cross-checking drug infor-
mation, protocol parameters, and patient records may also be

provided, and dosage adjustment assistance may be provided based on laboratory blood values by use of pharmacokinetic algorithims (or through the use of special calculators enabling the patient to apply results of test done in the

5 home or other non-laboratory environment) for fine adjustments of the dosage scale.

The system and method of this invention thus permits virtually unlimited programming capabilities without compromising the size and weight of the delivery unit.

10 Conversely, by freeing the system from size constraints, virtually unlimited programming capabilities may be included within the system, and yet the delivery unit (which may be worn by the patient) can be smaller than even less sophisticated devices.

15 This unlimited programming capability, or power, thus provides an ability to program single or multiple channels with each of the multiple channels being capable of having different drugs and individually specified delivery profiles and with the machine code of the delivery unit being auto-

20 matically programmed for each channel, as well as an ability to assign, by programming, manual or event synchronized input sources to any designated delivery channel.

Description of the Drawings

The accompanying drawings illustrate a complete embodiment of the invention according to the best mode so far devised for the practical application of the principles thereof and in which:

5   FIGURE 1 is a block diagram of the device of this invention with patient interaction being also indicated;

FIGURE 2 is an expanded block diagram of the programming unit shown in FIGURE 1;

10   FIGURE 3 is a block diagram of the delivery unit, similar to that shown in FIGURE 1, but illustrating use of the control a unit to control plurality of channels through which therapeutic agents may be delivered to a patient;

FIGURE 4 is an expanded block diagram of the control

15 unit shown in FIGURE 1;

FIGURE 5 is a graph illustrating a typical constant rate profile for therapeutic agent delivery during a one day period;

FIGURE 6 is a graph illustrating a typical multilevel approximation to the toxicity limit for therapeutic agent delivery during a one day period; and

FIGURE 7 is a graph illustrating a typical series of
5 boli (discrete shots) of therapeutic agent delivery spaced over a one day period and illustrating limitations in dose rate due to varying toxic susceptibility.

Description of the Invention

The block diagram of FIGURE 1 summarizes the inter-
10 connection the components, or elements, of the device of this invention. As shown, device 11 includes, primarily, a programming unit 13 and a delivery unit 14.

Programming unit 13 includes a computer 16, preferably a general-purpose computer, that is capable of programming
15 programmable logic unit 18 used to control operation of delivery unit 14 when placed in delivery unit 14 (as indicated in FIGURE 1). As also indicated in FIGURE 1, by way of example, computer 16 has machine program 20 connected therewith, as well as databases 22, assistive programs 24
20 and pharmacokinetic programs 26, as needed, for programming the logic unit.

Obviously, computer 16 could also have connected therewith any number of other input devices, such as a keyboard, graphics, tablet, joystick, "mouse", or other

manipulanda, or other data acquisition devices. In addi-

tion, computer 16 can also be connected with one or more

displays 28, which, by way of example, could be a video

screen, a liquid crystal display, a printer and/or or a

5 plotter.

Logic unit 18 is preferably a programmable logic

cartridge. Programmable logic cartridge 18 may be any form

of non-volatile logic (meaning the programmed form will be

retained in the absence of electrical power) or otherwise

10 volatile logic sustained by an accompanying power source,

such as a small back-up battery. Preferred forms or such

components include, but are not meant to be limited to,

commercially available devices such as programmable read

only memories (PROMs), erasable programmable read only

15 memories (EPROMs), electrically erasable programmable read

only memories (EEPROMs), electrically alterable programmable

read only memories (EAPROMs), nonvolatile random access

memories (NVRAMs), and programmable logic arrays (PLAs).

The logic cartridge contains the configurable portion

20 of the logic path of the control unit and establishes

operation thereof depending upon the contained configuration

of logic gates or states in the delivery unit. Program 20

is a machine program that is used to operate computer 16,

and the system transforms the user-provided information into

a logic configuration suitable for operating the delivery

unit in accordance with the intended delivery requirements

of the user. Computer 16 then writes the configuration into

logic cartridge 18 and automatically verifies correct entry.

In assisting the user to enter error-free information,

the computer uses appropriate databases 22 and assistive

programs 24 to determine inconsistencies, to offer the user

supporting information and/or to aid calculations, as

indicated in greater detail in FIGURE 2. Databases(DBS) 22 can

.0 therefore include, by way of example, patient DBs 22a and

drug DBs 22b. These can be augmented by assistive programs

24 (such as protocols 24a, unit definitions 24b, and

graphics 24c), and by pharmacokinetic algorithms 26 to

thereby provide information such as accepted drug dosage

15 ranges, interactions between drugs when present in the

patient at the same time, and parameters for mathematical

dose-response or pharmacokinetic models for each drug.

By using these databases and assistive programs, the

computer is able to automatically interpolate from the

20 preferred nomenclature of the user and units of measurement

to those needed by the logic of the delivery unit (hereto-

fore, the user was required to perform numerous calculations

before being able to adjust a delivery unit, each such

calculation carrying a finite probability of introducing

error).

The computer is also able to utilize the databases to

retain the history of the individual patient's treatment and

5   responses, and the patient's pertinent physiological or

other parameters used to assist determination of safe and

effective dosage. Furthermore, the computer uses a

"library" of delivery protocols, either provided by the

manufacturer, developed by the user, or provided by a third

10   party. Such protocols assist the user by requiring only the

minimum amount of data needed to correctly adjust the dosage

to an individual patient.

The computer may also use pharmacokinetic, pharma-

codynamic, or dose-response models (designated generally by

15   the numeral 26 in FIGURES 1 and 2), to either aid program-

ming of the delivery profile of the delivery unit, or to

simulate the outcome of a profile in terms of resulting

bodily concentrations of the delivered substances, or both.

Furthermore, such programs may aid the user in finally

20   adjusting dosages after taking requirements of substance

concentrations within the body of the patient at some time

intervals after beginning delivery. Such data may be

acquired from a clinical setting, such as a hospital lab-

oratory 30, as generally indicated in FIGURE 1, or in the

patient's own normal surroundings by means of simplified tests.

Data may then be entered into the programming computer for programming a new logic cartridge, or may be communicated to the delivery unit. In the latter case, the logic cartridge contains sections of configurable logic suitably different from the base configurations so as to allow small changes in effective dosage rates from the base program.

The suitable interpolation of a concentration measurement to a logic configuration or selection is normally automatically accomplished in the programming computer, but may be accomplished by a calculator 32 (operated by patient 34) which has the ability to communicate with the delivery unit under special circumstances such as, for example, in response to patient perception of clinical symptoms.

As brought out more fully hereinafter, a patient, or an event, is also able to initiate delivery of the therapeutic agent, as generally indicated in FIGURE 1 by the block entitled demand or event 36, the output from which is coupled to delivery unit 14.

As also indicated in FIGURE 2, data is written into logic cartridge 18 by computer 16 through converter 38, with the computer also providing, if desired, an output to labeler 40 (which provides a suitable label for attachment

to the logic cartridge). As also indicated in FIGURE 2,
computer 16 may also be connected with delivery unit 14
through a telephone interconnect system 42 that includes
modems 44 and 46 at opposite sides of telephone system 48,
5 for purposes as described more fully hereinafter.

Delivery unit 14 includes a control unit 50 which
receives removable programmable logic unit 18. Control unit
50 drives a driver 52, which driver, in turn, controls
operation of an applicator, such as a syringe 54, through
10 which the therapeutic agent is delivered to patient 34.
Delivery unit 14 will not operate if logic unit 18 is
removed from control unit 50.

The driver mechanism may be of any suitable form, and
may be, for example, a mechanism that depresses the plunger
15 of a syringe, as is now preferred, with all components
contacted by the fluid drug formulation being preferably
disposable.

The delivery unit may contain a plurality of inde-
pendently controlled fluid delivery channels as indicated in
20 FIGURE 3. When so utilized, control unit 50 independently
controls each driver (indicated by the numerals 52a-d in
FIGURE 3), and each driver controls a separate syringe
(indicated by the numerals 54a-d in FIGURE 3) with each

driver and syringe establishing separate channels (indicated in FIGURE 3 as channels 1-4).

The preferred embodiment uses a modular design assembly in which any number from one to four channels may be used at

5 any one time. More than one delivery unit assembly may, however, be synchronized together for applications requiring more than four fluid channels.

In its preferred form, the controller logic consists of discrete logic elements so as to make up a state machine.

10 This state machine performs strict sequences of logic functions depending upon the state of a clock or other control element, or a combination thereof, and upon the state of the logic programmed into the logic cartridge. Alternately, combinational logic can be utilized in a dedicated control

15 machine, which again uses the configurable logic in the programmable cartridge to define the sequence of logic operations.

While the intended preferred embodiment of this invention utilizes a delivery unit without a microprocessor, the

20 delivery unit could include a suitably programmed microprocessor (or microprocessors), which reads operating parameters from the information contained in the programmable memory cartridge which is programmed remote from the delivery unit.

The electronic controller 56 of control unit 50 also
utilizes a read/write memory 58 (see FIGURE 4) within the
delivery unit to record data about the actual operating
history over a time period, for example, a number of days,
5 and can include coding of date and time of day, if desired.
Such data are useful for various purposes, including diag-
nosing hardware problems, recording data of patient-demanded
delivery events, recording data on physiologically -or
blood-level-controlled delivery profiles, and/or compiling
10 data on the patient's compliance with a prescribed delivery
schedule.

The delivery unit may, depending upon the application,
use manually-operated controls 60 (connected through ports
62 to controller 56 as indicated in FIGURE 4) to synchronize
15 delivery events of any complexity with the detailed waveform
and amplitude information relating to the events being pro-
grammed into the logic cartridge. Such manual controls may
operate any of the available channels, the assignment being
made by appropriately programming the logic cartridge.

20 Similarly, delivery events may be synchronized by
detecting, as by sensors 64 as indicated in FIGURE 4, the
occurrence of a physiological event or by appearance of a
critical level of a substance in the blood or other
physiological fluid. Of greater complexity, the profile of

fluid delivery over time may change in accordance with
direct modulation from the detected levels and/or
statistical behavior of physiological events, or from
detected levels of substances in the blood or other
5 physiological fluids.

The computer can also communicate with the delivery
unit remotely by means of the telephone interconnect unit
42. In this case, communication is normally restricted to
hardware problems diagnosis, routinely report patient usage
10 information, or to slightly adjust dosage rate.

As also shown in FIGURE 4, control unit 50 includes
electronic controller 56 capable of dividing time into time
segments, such as, for example, one-minute intervals,
utilizing clocks 66. Typically, clocks 66 follows a twenty-
15 four hour clock in real time. At each time segment, the
controller addresses the logic cartridge and performs a
series of housekeeping checks, then looks to see if a
delivery event is scheduled.

Since the computer programs the logic cartridge, the
20 computer preferably uses programs that translate the user's
expression of delivery profile into time-encoded series of
discrete delivery pulses. Mathematically, the programs
encode a combination of both pulse-width modulated and
pulse-period modulated trains of delivery events. The

computer then synthesizes a flow profile using relatively

rapid trains of pulses.

Examples of some of the more simple profiles are shown

in FIGURES 5, 6 and 7. In these examples, the wave-like top

5   line represents an exemplary toxicity limit of a patient

which limit varies with a twenty-four hour rhythm. The

objective of optimizing flow rate is achieved by delivering

the therapeutic agent at a rate which comes close to the

toxic limit, but never exceeds it.

10   FIGURE 5 shows a typical constant rate profile deliv-

erable by many delivery systems now known, and FIGURE 6

shows a typical multilevel approximation to toxicity limit,

while FIGURE 7 shows the results of a typical series of boli

(discrete volumes) spaced variably in time and limited in

15   dose content by the varying toxic susceptibility.

The delivery unit is not dependent upon the size or

type of mechanical drive being used. The controller would

work just as well with a small capacity element, such as,

for example, a 0.1cc/day capacity, as with a large capacity

20   element, such as, for example, a 2000cc/day capacity driver

element. It would also work equally as well with other

drive mechanisms, such as, for example, a pulsatile solenoid

drive or a continuous-flow proportional regulator, as with

the syringe drive.

-21-

Since the computer designs the delivery profile for each channel, based on the specifications of the user, not only can each channel be made to operate independently, the channels can also be linked in operation relative to one

5   another to allow greater operating flexibility. For example, while a particular delivery unit might offer up to four channels of 35cc of a therapeutic agent each, when two channels are operated in series or in tandem, the result is to allow 69cc capacity for a particular therapeutic agent

10   (such as a relatively insoluble drug, for example).

Of major importance is the fact that this capability has been designed without requiring microprocessors in the controller. While microprocessors are powerful, they may have several significant limitations, including higher

15   costs, limited availability, and software provability limitations (at least without use of multiple units to provide a cross-check).

All of the "intelligent" features are included in the programming unit. This allows the delivery unit (which is

20   the key component in the patient's view) to be kept simple, have a low cost, and yet be highly reliable. If desired, however, the delivery unit can provide displays (such as displays 68 connected with controller 56 as indicated in FIGURE 4).

-22-

The programming unit is far more powerful and friendly than known systems, which attempt to fit sophisticated controls into small size and thus compromise both size and user friendliness. In addition, the system of this

5 invention, uses partitioning (i.e., programming in a separate unit from that of the delivery unit) which is a major departure from known practice.

The programming unit prompts the user (such as a pharmacist) for patient and prescription data. Basic

10 protocol information may be requested from a database to speed data entry. The protocol outline asks only for the minimum amount of data needed to individualize dosages to the patient.

Protocols are derived from published sources, third

15 parties, or are developed by the user. In the latter case, friendly software is preferably provided to assist the user by asking a series of questions. All protocol entries and changes may be preferably date/time coded to provide a complete audit trail.

20 If requested, the computer queries a drug database to check for dosage range errors and for compliance with package insert labeling. It also checks for possible adverse drug interactions. The user may over-ride certain

types of warnings by providing signature for the audit trail
held in the permanent patient record.

The provided software may, if desired, cause the
computer to look up the patient's history on the patient
5 database to check for consistency. Again, the user may
over-ride certain warnings with appropriate security
precautions. The patient's records are automatically
updated upon the users verification of correct entry.

The computer can be used not only to manage each of the
0 infused drugs, but other drugs as well. It also charts the
responses of the patient to therapy, or any laboratory
measurements.

The computer is thus utilized as far more than just a
delivery unit programmer. It is a comprehensive medication
5 management system. The user can also ask the computer to
use pharmacokinetic algorithms to help derive optimum
profiles for a patient. The algorithm prompts for
laboratory data and may, if requested, remind the user of
the correct sampling protocol.

0 When the user indicates program acceptance, the
computer writes the data into the logic cartridge and
automatically verifies its contents against the original
image. If desired, the computer can cause a label to be
printed, in appropriate pharmacy form, for placement on the

cartridge. Finally, the computer may cause a hard copy of the patient's updated record to be printed, and copies all data into the patient database.

The programmable logic cartridge is a nonvolatile
5 memory (it does not lose contents with power loss). It may be used either as a one-time disposable, or as a reprogrammbale cartridge. The former provides relatively low cost with ultimate data security. Disposability assures the least chance of a mixup, which is possible with re-use. The
10 old cartridges may be included in the patient's permanent physical file for medico-legal backup.

Although microprocessor-based devices use read-only memories, they use them for the microcode of the processor, and not for the user program - which is in the random-access
15 memory (RAM) unit with presently known systems. In addition, known systems, despite containing one or two microprocessors, have only a very limited "vocabulary" of permissible flow profiles. To change the profile, the machine microcode must be rewritten, which is quite
20 difficult and cannot normally be done by the user. Such systems are therefore rigidly limited in capability despite the use of relatively complex computing chips which are required to manage these very simple functions, with most of

the sophistication of such a process being used to manage manual controls and displays.

Unlike the more commonly used RAM unit which is designed for high-speed writing as well as reading at low
5 voltages and is thus relatively susceptible to electrical noise as well as being volatile, the logic cartridge used in this invention is exceedingly resistant to environmental electromagnetic noise.

Most significantly, the logic memory unit is used as a
10 configurable logic, and not as a simple table of parameters to be looked up. This gives the system of this invention enhanced programming power.

As can be appreciated from the foregoing, this invention provides an improved system and method for
15 application of a therapeutic agent to a patient.

WHAT IS CLAIMED IS:

1.   A device for effecting application of a
therapeutic agent to a patient, said device comprising:

application means including delivery means adapted to
deliver a preselected therapeutic agent to a patient with
said delivery means having a controllable element for
controlling the flow of said therapeutic agent from said
delivery means, and said application means also including
electronic means for controlling said controllable element
with said electronic means including removable programmable
means for establishing a flow profile for said delivery
means when said programmable means is programmed and
operatively positioned at said application means; and

programming means operationally independent of said
application means for programming a then selected flow
profile into said programmable means while said programmable
means is removed from said application means to thereby
enhance the integrity of said then selected flow profile
during subsequent use while operatively positioned at said
application means.

2. The device of claim 1 wherein said application means includes a syringe, and wherein said controllable element includes a driver for driving said syringe.

5   3. The device of claim 1 wherein said programmable means is a logic cartridge which is operationally non-volatile.

4. The device of claim 1 wherein said programming means is a general-purpose computer and said

10 device includes program means connected with said computer to provide database and assistive programs so that said computer is responsive to patient and drug information, as well as protocol and unit definition information when programming said programmable means.

15   5. The device of claim 1 wherein said programmable means is programmed by said programming means to cause said flow through said delivery means to deliver said therapeutic agent by one of a time-based and an event-synchronized flow profile.

20   6. The device of claim 1 wherein said delivery means includes channel means defining a plurality of channels for separately delivering therapeutic agent, wherein said controllable element includes a plurality of controllable units each of which is associated with a

25 different one of said channels, wherein said programmable

means controls each of said controllable units, and
wherein said programming means programs said programmable
means so that each of said units operates independently of
one another whereby independent flow profiles are
established for each of said channels.

7.   The device of claim 1 wherein said
application means includes a controller and memory means
connected with said controller for recording the history
of therapeutic agent flow from said device.

8.   A device for effecting application of a
therapeutic agent to a patient, said device comprising:
        drive means for controlling delivery of a
preselected therapeutic agent to a patient;
        electronic means including a removable
programmable logic cartridge for establishing a flow
profile to control operation of said drive means when said
programmable logic cartridge is programmed and operatively
positioned; and
        computer means for receiving said removable
programmable logic cartridge and programming the same with
a then selected flow profile based upon predetermined
parameters of patient need and therapeutic agent
capabilities.

9.   The device of claim 8 wherein said device
has a plurality of channels for separately delivering
therapeutic agent to a patient, and wherein said drive

means includes a driver associated with each of said

channels, with each of said drivers being controlled by

said programmable logic cartridge, and with said

programmable logic cartridge being operationally

5   non-volatile and programmed by said computer means to

effect a separate flow profile for each of said channels.

10. A device for effecting application of a

·therapeutic agent to a patient, said device comprising:

delivery means adapted to deliver a preselected

10   therapeutic agent to a patient and having a controllable

element for controlling therapeutic agent flow from said

delivery means; and

electronic means for controlling said

controllable element and including a pre-programmed

15   removable programmable means for establishing a flow

profile from said delivery means when said programmable

means is operatively positioned at said device.

11. The device of claim 10 wherein said

delivery means includes a syringe, wherein said

20   controllable element includes a driver for driving said

syringe, and wherein said programmable means includes a

logic cartridge that is operationally non-volatile.

12. The device of claim 10 wherein said

delivery means has a plurality of channels for separately

25   conveying therapeutic agent therethrough, wherein said

controllable element includes a controllable unit each of

which is associated with a different one of said channels, and wherein said programmable means is pre-programmed to effect a separate flow profile for each of said channels.

13. A method for effecting application of a therapeutic agent to a patient, said method comprising:

providing delivery means adapted to deliver a preselected therapeutic agent to a patient;

controlling operation of said delivery means through electronic means that includes a removable programmable element which, when operatively positioned, establishes the flow profile of said delivery means; and

pre-programming said programmable element while removed from said application means.

14. The method of claim 13 wherein said method includes providing a programmable logic cartridge that is operationally non-volatile as the programmable element with said logic cartridge being programmed while removed from said delivery means by use of a general-purpose computer.

15. The method of claim 13 wherein said method includes providing a delivery means having a plurality of channels through which therapeutic agents are separately conveyed for delivery to a patient and separately controlling the flow of therapeutic agent through each of channels by said programmable element by pre-programming

said programmable element to establish a separate flow profile for each of said channels.
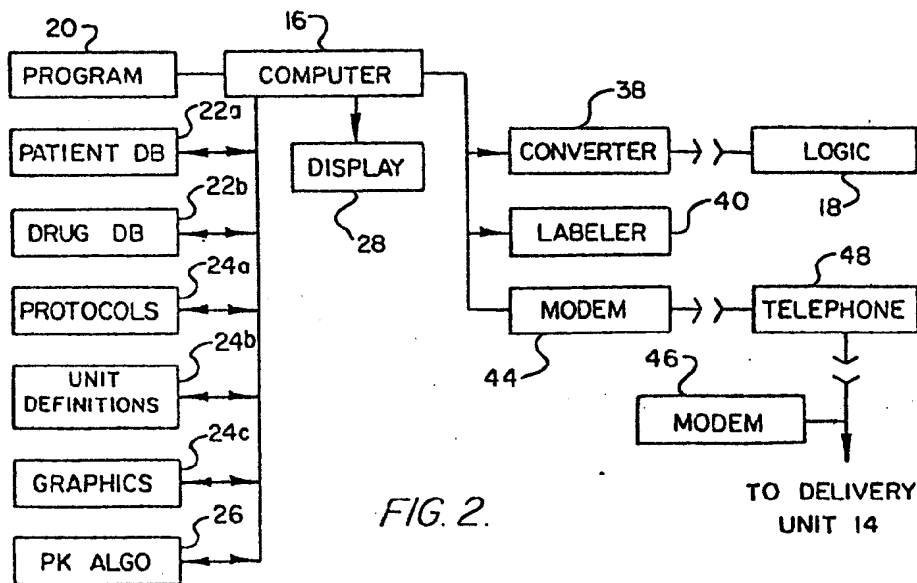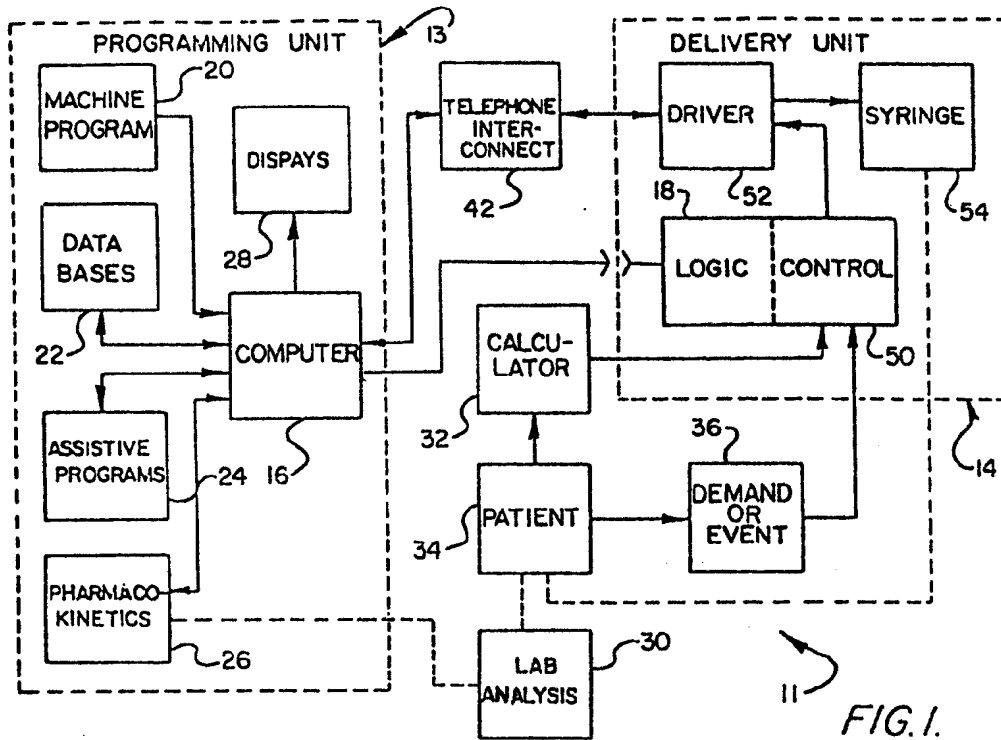
16. A method for effecting application of therapeutic agent to a patient, said method comprising:

5   determining the parameters of flow for a preselected therapeutic agent with respect to a predetermined patient;

programming a programmable element with a flow profile according to the determined parameters of flow for

10 said preselected therapeutic agent; and

using said programmable element to control flow of said predetermined therapeutic agent to said patient.

17. The method of claim 16 wherein said method includes determining the parameters of flow for a

15 plurality of preselected therepeutic agents with respect to a predetermined patient, programming a programmable element with a flow profile according to the determined parameters of flow for each of said preselected therapeutic agents, and using said programmable element to

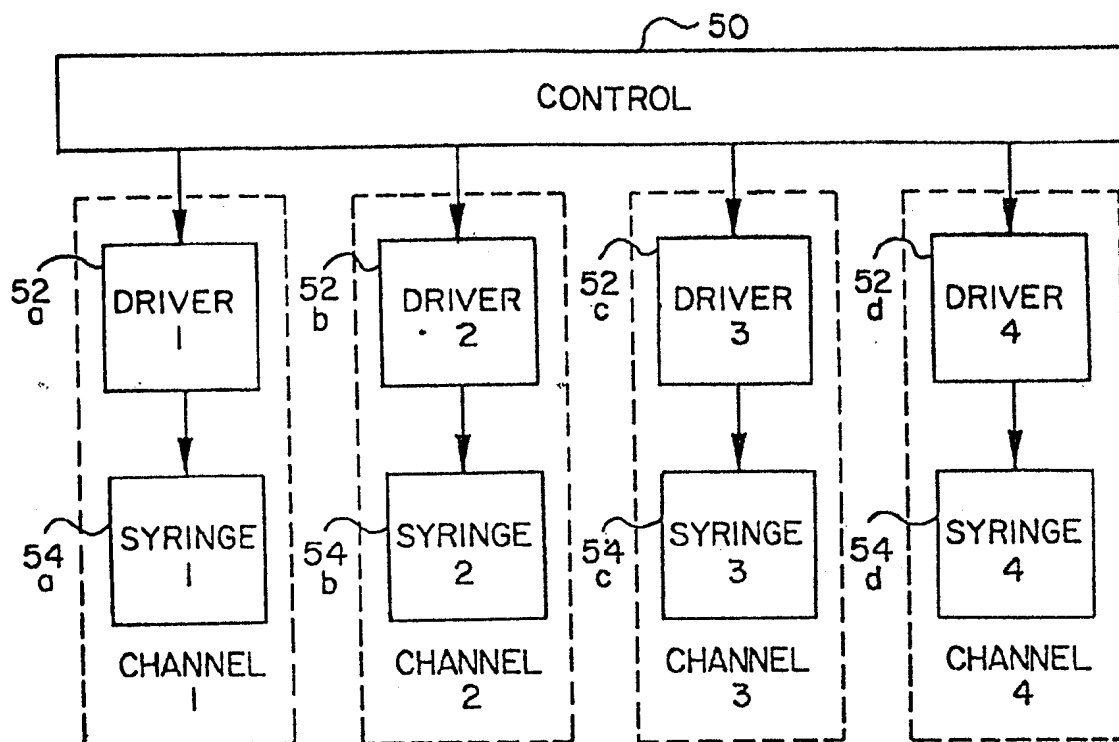20 separately control flow of said preselected therapeutic agents to said patient.
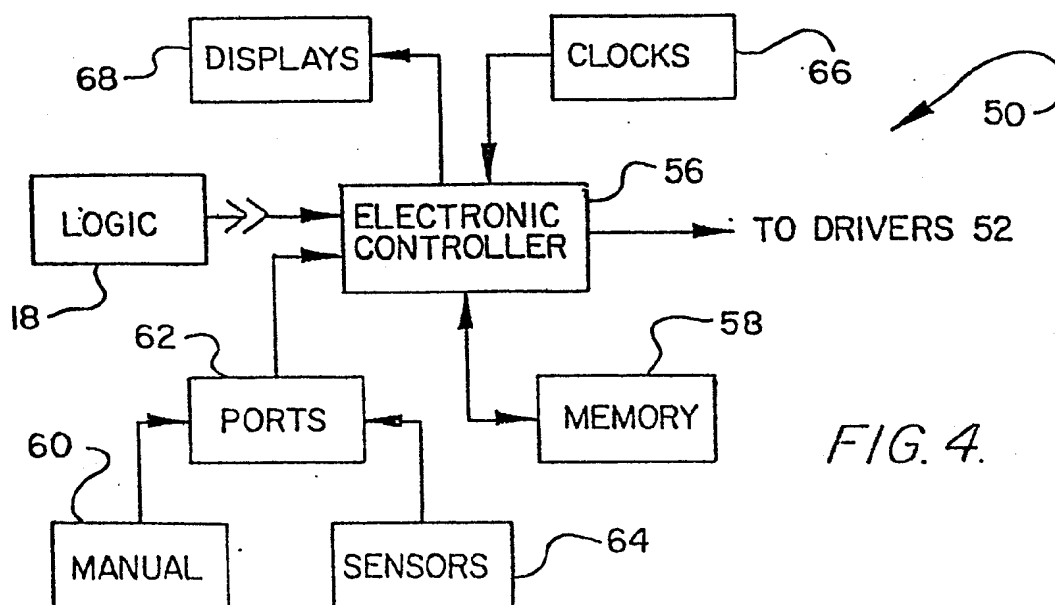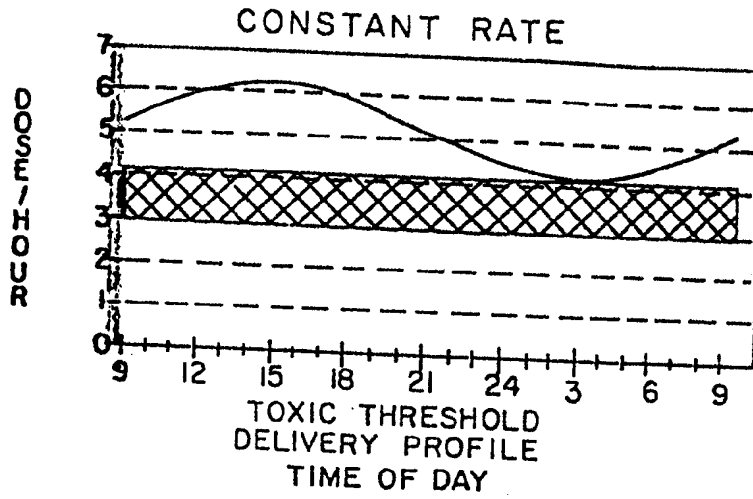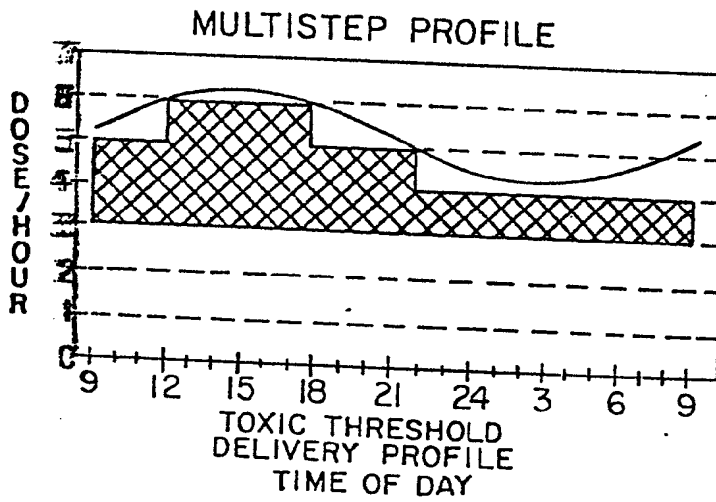
FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

CONSTANT RATE

FIG. 5.

TOXIC THRESHOLD
DELIVERY PROFILE
TIME OF DAY

MULTISTEP PROFILE

FIG. 6.

TOXIC THRESHOLD
DELIVERY PROFILE
TIME OF DAY

BOLUS SERIES

FIG. 7.

TOXIC THRESHOLD
DELIVERY PROFILE
TIME OF DAY